Rock Chips

Summer 2006

Alberta Geological Survey

New Heavy Mineral Results Spark Exploration Activity in Northwest Alberta

On March 1st, the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) released the joint publication AGS Special Report 77/GSC Open File 5121, which has since prompted significant mineral staking activity by mineral exploration companies. The report presents heavy mineral and geochemical results from glacial drift samples collected in the Zama Lake (NTS 84L) and Bistcho Lake (NTS 84M) map areas (Figure 1).

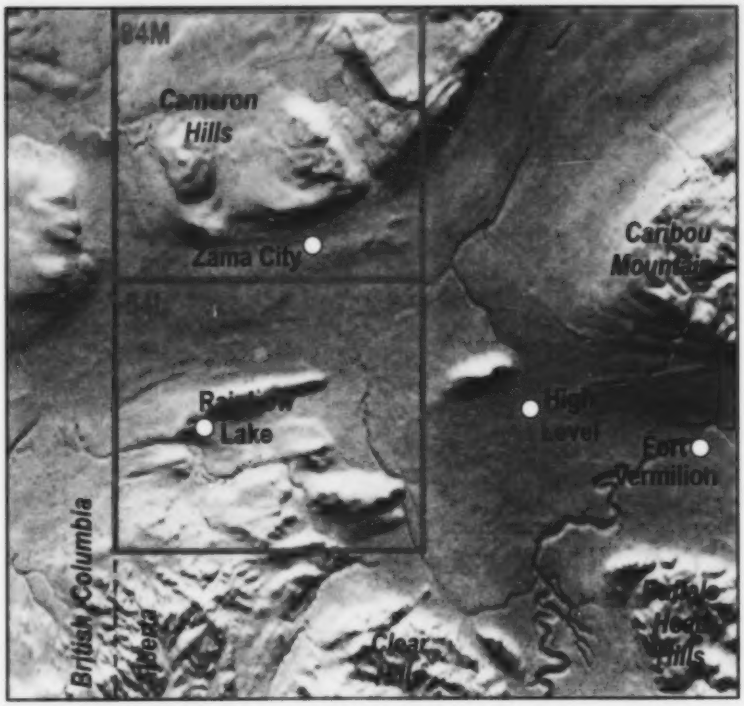

Figure 1. Location of the survey area where the results of regional reconnaissance Fort Vermilion samples were jointly published in AGS Special Report 77/GSC Open File 5121.

Results stemmed from reconnaissance-scale sampling of till and glaciofluvial sediments, as well as subsequent heavy mineral and geochemical analyses undertaken to assess the occurrence of kimberlite indicator minerals (KIMs) and other economic minerals. These glacial sediment sampling surveys were conducted during the surficial mapping as part of a collaborative project between the AGS and GSC, under the GSC's Northern Resource Development Program (NRD Project 4450), with additional support through the Targeted Geoscience Initiative (TGI-2). The project study area extended into northeast British Columbia and involved the participation of the British Columbia Ministry of Energy, Mines and Petroleum Resources (BCMEMPR).

The joint report outlines the presence of low concentrations of KIMs and high concentrations of sphalerite grains. These results highlight the potential for primary bedrock-hosted deposits of zinc and diamonds. This immediate response by the exploration industry indicates the relevance of this collaborative project. Results from 70 glacial sediment samples in northwestern Alberta indicated KIMs generally consist of minor amounts of pyrope and chromite (Figure 2), which remains to be assessed by microprobe analyses. However, of particular significance, and the focus of this report, is the discovery of a sphalerite dispersal train in the south-central sector of the Bistcho Lake (NTS 84M) and north-central sector of the Zama Lake (NTS 84L) map areas. This dispersal train consists of anomalous concentrations of sphalerite grains with minor galena. For example, a single 30 kg till sample

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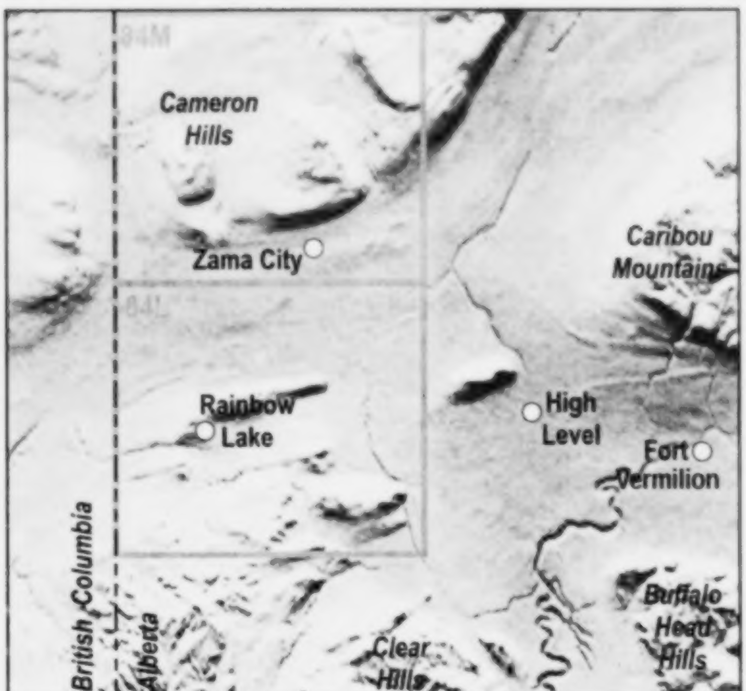

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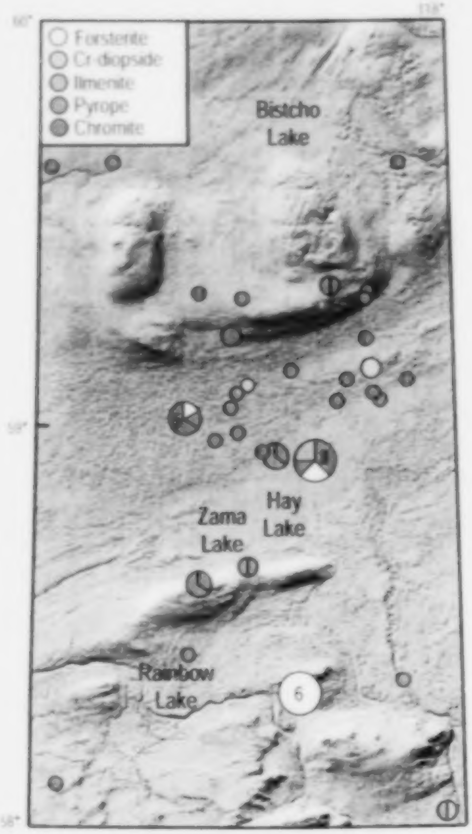

Figure 2. Occurrence of kimberlite indicator minerals in glacial sediment samples. The smallest circles represent a single grain; larger grain counts indicated by number.

yielded >1200 sphalerite grains (0.25 to 2.0 mm) and 4 galena grains (Figure 3).

Surficial mapping and ice flow studies in the region indicate it is unlikely the sphalerite-bearing till is the product of long-distance glacial transport from the Pine Point Mississippi Valley Type Pb-Zn deposit on the southern shore of Great Slave Lake, Northwest Territories. The survey area was inundated by ice emanating from the Keewatin Sector of the Laurentide Ice Sheet during the Late Wisconsin glaciation (~22 000 to 10 000 years Before Present). At the onset of glaciation, topographically confined lobes of ice advanced into the region. At glacial maximum of the Late Wisconsin Laurentide Ice Sheet, ice flowed westward across the region toward the Rocky Mountains (Figure 4), where it abutted the Cordilleran Ice Sheet and became deflected north and south along the mountain front. The Zama Lake area lies in the vicinity of this north-south flow divide. The significance of this is that during glacial maximum, ice crossing the Pine Point ore deposit would have travelled north of

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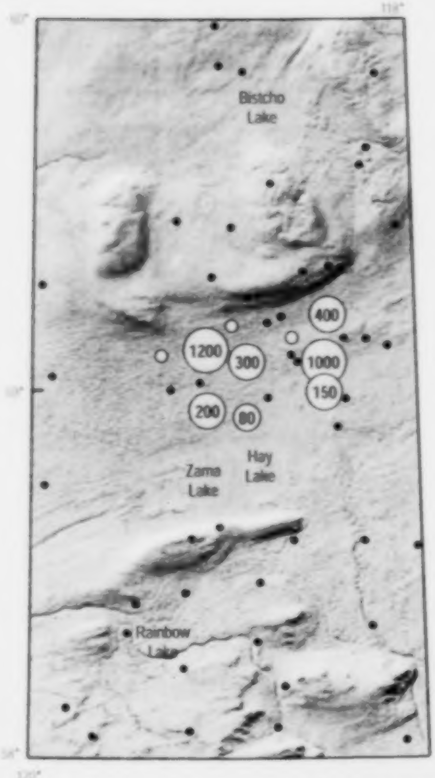

Figure 3. Occurrence of sphalerite grains in glacial sediments samples. Small orange circles indicate a single grain count; black circles represent heavy-mineral samples with no sphalerite recovered.

the Cameron Hills, and well north of the Zama Lake sphalerite anomaly (yellow star, Figure 4). Extensive fluted and otherwise glacially moulded terrain (smaller arrows, Figure 4) exhibit a number of crosscutting and, at times, topographically confined flows. Many of these streamlined landforms formed during deglaciation when the ice sheet retreated as a series of lobes. Similarly, during initial ice advance at the onset of the last glaciation, topographically confined lobes may also have advanced across the region. Thus, it is possible that material from the Pine Point region was transported toward Zama Lake during the early or late stages of the last glaciation. However, sphalerite minerals were recovered from basal till dug from >3 m depth, suggesting they were deposited during full glacial, as opposed to deglacial time.

Aside from the regional ice-flow history, there are several factors that argue against the sphalerite and galena anomalies being the product of long-distance glacial transport, comminution, and deposition of erratic material from the Pine Point area, and instead favour a nearby bedrock source. First, the sphalerite grains were recovered from basal till sampled at >3 m depth, which most likely reflects a nearby source. Second, the six samples with high sphalerite grain counts (and four with lesser concentrations) are in a geographically restricted area north of Zama Lake. Third, geochemical analyses of the silt and clay-sized fraction do not reveal proportionally elevated concentrations of lead and zinc.

Figure 4. Late Wisconsin regional ice-flow history for northwest Alberta derived from the recently published EUB/AGS/GSC surficial geology maps. Laurentide Glacial Maximum (LGM).

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suggesting that glacial comminution of sand-sized sphalerite and galena has been limited. Fourth, close examination of the mineral grains shows some grains have strong primary crystal structure and subangular to angular morphologies, which would not have survived extensive glacial erosion and transport (Figure 5).

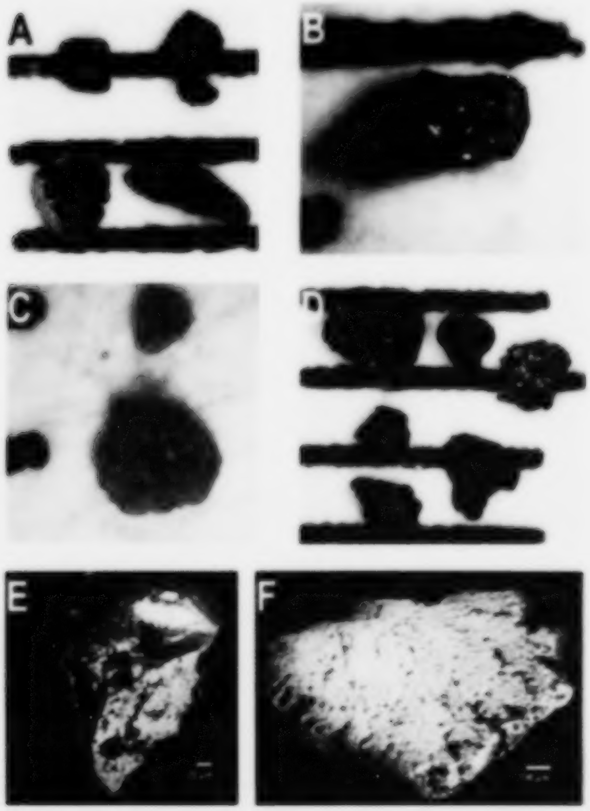


Figure 5. Photomicrograph of the various heavy mineral grains recovered; 1 mm scale bar (space between the green lines) is provided for images A to D. A) galena grains exhibiting cubic crystal structure; B) purple pyrope; C) resinous honey sphalerite (cleophane); D) dark grey to black zinc-rich sphalerite, a majority of the grains recovered were of this nature; E) scanning electron microscope (SEM) image of an angular sphalerite grain; F) SEM image of a sphalerite grain with a glacially polished surface.

Twenty additional glacial sediment samples collected up ice-flow of the Zama Lake anomaly have been submitted for heavy-mineral analysis and should help constrain the geographic extent and possible origin of the sphalerite anomaly. Chemical and isotopic analyses of the sphalerite and galena grains are also planned to further determine their origin. ❖

Geological Puzzle

Unscramble each word. Then use the marked letters to solve the second puzzle. **HINT**: All of the words have to do with projects AGS works on.

YLEHYROGDOGO	13
CADI ASG	15
BCKREDO	20
IPMNPGA	
SIEETWB	4
GNREEY	3
GSA	
LCOA	12
RHDEOGZAAS	10
MISNDDOA	
DALSIONS	11
CLBODEA HEEAMNT	3
CRNBOA DDXIIOE	21
LMEANISR	2
SIURFACLI GYLOOGE	19, 1, 22
85 YARE SOHYRIT	6
FNIO EALSS	7
SBTPNCUIAOLI	14
IGS	8
RNAUIMU	5
ODEGUANRRWT	16
LGEGYOO	17
MORETE GENNSIS	18

1 2 3 4 5 6 7 — 8 9 10 11 12 13 14 15 16 17 — 18 19 20 V 21 22

Travel Through Time — A Day on the North Saskatchewan River

On May 5, 2006, five geologists of the Alberta Geological Survey led a river-raft field trip down the North Saskatchewan River as part of Alberta's Environment Conference. The journey offered a glimpse of the past 60 million years of Edmonton's natural history, made possible by one of nature's time machines: the North Saskatchewan River.

The ancestral river has been flowing across the prairies for millions of years within the broad, shallow-sloped Beverly Valley. Parts of that valley underlie the central part of Edmonton, the deepest parts beneath the City Centre airport and N.A.I.T.

About 27 000 years ago, a major glacier from the northeast advanced over the Edmonton region and it, along with Glacial Lake Edmonton, deposited thick sediment, completely burying the Beverly Valley and masking any present-day surface expression.

The part of the river valley that is presently exposed in Edmonton is only about 12 000 years old, which is relatively recent in geological time. It was formed by the re-establishment of the regional drainage following the retreat and melting of the glaciers, but this time along a different path than the Beverly Valley.

Over the last 12 000 years or so, the river has carved down through soft sediments deposited by the glaciers, and into the harder Cretaceous sedimentary rocks, forming a series of relict terraces, separated by relatively steep erosional walls.

The raft trip started in the southwest section of Edmonton at Terwillegar Park and continued along the North Saskatchewan River to Rafter's Landing just south of the downtown area.

The satellite image on this page shows the field trip stops and points of interest along the way. The following pages describe the points in further detail.

Modified from an image compiled from Alberta 2001 natural colour mosaic and Alberta 2002 IRS Mosaic provide by Photosat.ca. Alberta STRM purchased from US Geological Survey EROS Data Center.

L- Lunch Stop M- Muster Point JMB - James Macdonald Bridge

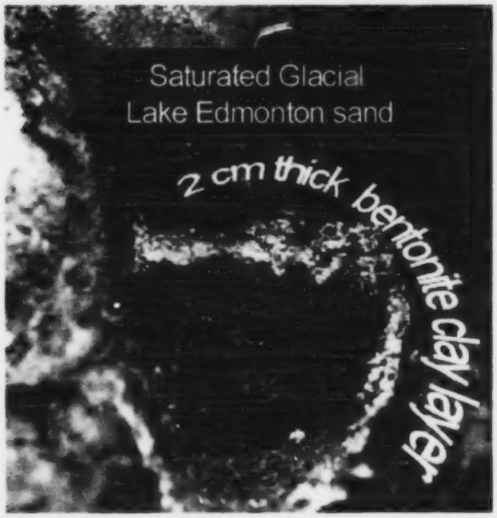
1 Walk to observe outcrop of preglacial sand of the buried Stony Valley in the Big Bend Section. Outcrops of Horseshoe Canyon bedrock units with valley incision, preglacial sand, glacial sediments - till and lake sediments.
2 Whitemud Road landslide and mechanisms for slope failure.
3 Aufeis and groundwater discharge related to the buried New Sarepta Valley.
4 Laurier Park Lunch Stop and gold panning demonstration.
5 Keillor Road instability and slope failure.
6 Hawrelak Park - reclaimed former gravel pits.
7 Slope instability along Summit Drive and landscape armouring.
8 Mazama ash at High Level Bridge.
9 Put out at Rafters Landing - Grierson Hill instability, rip-rap along bank, reclaimed landfill of Connor Hill (Edmonton Ski Club), Muttart Gardens, coal mines and Shaw Conference Centre.

Travel Through Time — A Day on the North Saskatchewan River

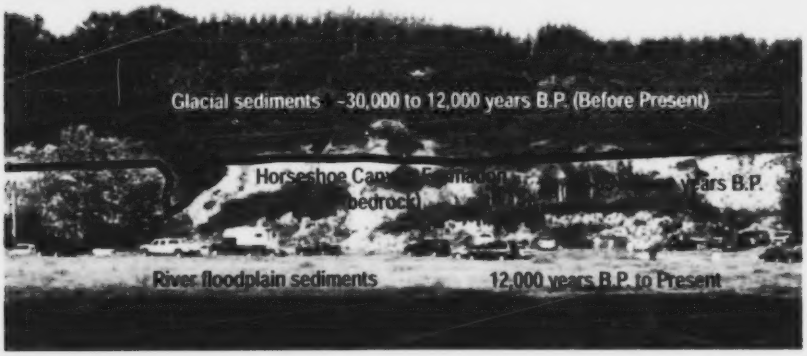
Stop 1: Muster Area and Terwillegar Park

Participants gather and unload the rafts at the launch site in Terwillegar Park in southwest Edmonton.

More than 65 million years of time are exposed in the geological record along the banks of the North Saskatchewan River at Terwillegar Park, spanning the Age of the Dinosaurs to the arrival of man in North America. Following the 'Law of Superposition,' the oldest units are at the bottom of the outcrops and the youngest are at the top. All of the major rock units one is likely to encounter in the Edmonton area are visible in Terwillegar Park along the outcrop known as the 'Big Bend Section.'



Bentonite is a member of the smectite family of clays that are known for their capacity to swell when wetted. It is one of the major causes for slope failure in the Cretaceous bedrock units in the Edmonton area, particularly after heavy rainfalls when the clays become saturated. However, the swelling properties make bentonite ideal for protective linings in landfills and waste pits, and for sealing pipes in the ground, such as protecting water wells from surface contamination.



A north view of the Big Bend Section showing the exposed bedrock of the Horseshoe Canyon Formation at the Terwillegar Park area.

The oldest rock unit exposed at Terwillegar is called the Horseshoe Canyon Formation. It is an assemblage of sandy and muddy rock sediments deposited by rivers flowing into an inland sea during the Cretaceous (~75 to 80 million years ago). Lush vegetation growing in quiet backwaters along these rivers were later buried by mud, eventually turning into coal. Episodic outbursts, from active volcanoes to the west, deposited thin layers of ash on the river sediments. These ash layers later transformed into clay through weathering processes and are referred to as bentonite or bentonitic clays. The ash layer marking the time of the asteroid impact that ended the dinosaurs has been eroded in the Edmonton area.

Participants prepare to launch the rafts from the Terwillegar launch site.

Two ancient river valleys are in the Terwillegar Park area. One is the Stony Valley, which is exposed at the park, and the other is the New Sarepta Valley, which is exposed downstream of the park.

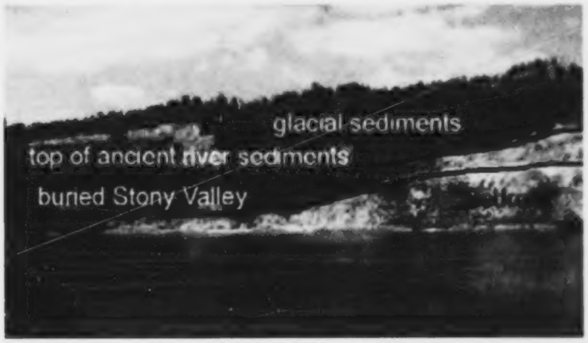
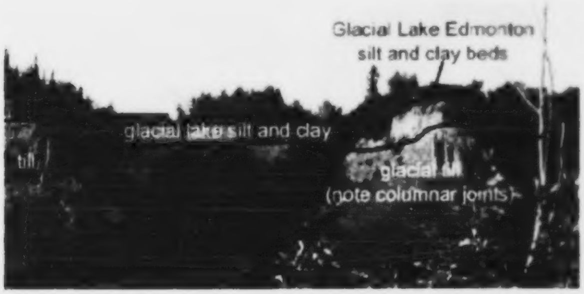


Photo showing the erosion of the bedrock surface by preglacial rivers.

In the last 2 million years, a number of major continental glaciers advanced from the northeast and covered most of Alberta. At Terwillegar, there is a record of only the latest glaciation, which occurred about 27 000 years ago. Ice in these glaciers was as much as 1.5 km thick in places and the weight of this advancing ice mass depressed the Earth's crust, causing the land surface to sink many metres.



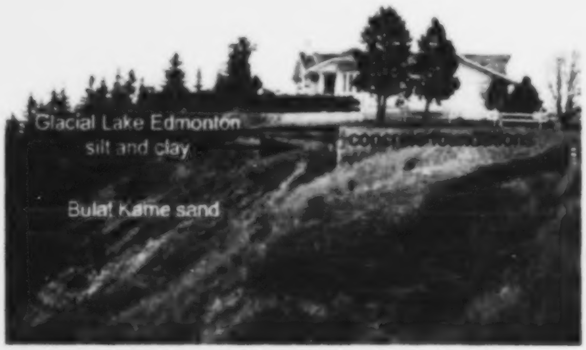
Exposure of glacial till and Glacial Lake Edmonton silt and clay. The sediment deposited by the glaciers is called till, which is composed of clay, silt, sand, gravel and boulders. Because these sediments were subjected to the weight of more than 1 km of ice in the Edmonton area, they are quite dense and stiff, and form vertical columnar faces on river outcrops.

Erosion continues today, but at a much slower rate than following the glacier retreat. Continuing adjustment of the landscape in response to the slow but steady erosion is demonstrated by the numerous landslides along the river banks.

Stop 2: The Whitemud Road Landslide

Much of the recently developed area in southwest Edmonton (Riverbend/Terwillegar) is located on a glacially deposited mound of sand called the Bulat Kame. The base of this sandy material was deposited in a channel formed beneath the glacier, which is now exposed in the river valley near Whitemud Road. At this location the surface material is a clay cap deposited by Glacial Lake Edmonton that rests on glacial sand, which in turn rests on till and bedrock of the Horseshoe Canyon Formation.

In October 1999, a portion of the river bank at Whitemud Road failed, carrying with it two residences and undermining three others. A detailed study highlighted the zone of failure to be within a weak bentonite layer in the bedrock.



Sheared house foundations at the Whitemud Road landslide.

The timing of the slide was likely due to increased development in the area. As the clay cap was removed during construction, more water infiltrated into the sands as people began to water their lawns. Another contributing factor was that the five-year period preceding the failure had a higher than average annual rainfall that added more water mass to the soil. Numerous groundwater discharge sites are evident along this section of the river, and there continues to be visible evidence of active slope instability. All of these factors contributed to the slope failure, but probably the most significant and obvious one is that the homes were located on a very sharp bend (meander) where the erosive forces of the river are greatest. Continued river erosion of the slide deposits along the sharp bend of the meander will progressively eat away at the toe of the slide, causing it to steepen, slump and fail even more over time.

Near-horizontal drains are being used to attempt to stabilize the banks at two locations.

Five houses were directly impacted by this landslide. The collapse of two of these homes down the river bank was captured on film. Other homes are still at risk of collapse.

Views of the Whitemud landslide.

Stop 3: Aufeis and Groundwater Discharge

Groundwater, while a valuable resource when you need water, can also be a hazard, particularly when there is too much of it in the wrong place. Directly north of the Whitemud Road landslide area is another potential landslide problem related to groundwater discharge from a channel aquifer in the buried New Sarepta bedrock valley. Water is an incompressible substance, so when the weight of the overlying material increases, it transmits that pressure to the pores between surrounding soil particles, effectively buoying them up and reducing the grain-to-grain friction. This increased pore-water pressure and resulting reduced shear strength of the sediment is the major mechanism for slope failure after heavy rainfalls.

Groundwater remains at a relatively constant temperature year-round, about 5°C to 7°C in the Edmonton area; therefore, it flows out of the river outcrop year round. In the winter, this discharge accumulates as ice, referred to as 'aufeis,' along the bank of the river, growing steadily in size until spring melt. The ice is visible long after the surface snow melts because of its greater thickness. During the summer months, the discharge may not be visible as the water can evaporate as quickly as it exits the ground, or as plants consume it during growth, but nevertheless, the water is always exiting along the bank year-round.

Frozen groundwater discharge from the buried New Sarepta Valley. View to the north from the Whitemud Road landslide.

Stop 4: Gold Mining in the Edmonton Area

Mining of placer gold and platinum in the Edmonton area preceded the discovery of gold in the Klondike by more than 40 years, and continues today with small, hobby operations. Placer gold was first discovered in the North Saskatchewan River valley in the 1850s by prospectors moving north from the United States into the British Columbia Cariboo area via Edmonton.

In 1867, 175 prospectors, known as the 'Overlanders,' left Eastern Canada passing through Edmonton on their way to the Cariboo gold fields. About a third stayed to try their luck in the Fort Edmonton area and settled on Miners' Flat. One of the first to mine the local gold was Thomas Clover, whose name survived as the districts of Clover Bar and Cloverdale. Gold mining in the Edmonton area peaked between 1895 and 1907, with some 300 miners working the bars 100 km upstream and downstream of Edmonton. Large steam-powered dredges enabled miners to extract up to two ounces of gold per day. In the last two years of operation, about 7500 troy ounces of gold were extracted, but profits were marginal and miners left to join the 1898 Klondike Gold Rush.

Participants pan for gold and check their results.

Stop 5: Keillor Road Landslide

In its heyday, Keillor Road was arguably one of the most scenic drives in Edmonton, with the road hugging the south riverbank near the Whitemud Equine Centre. However, it was doomed almost from construction, requiring constant maintenance to repair cracks. Slope instability was identified along Keillor Road in 1994, and the road was closed to vehicular traffic and converted to a pedestrian and bicycle corridor. In 1996, a significant slide occurred and a year later a concrete retaining structure was installed to stabilize the roadway. In 2001, cracks developed in the roadway behind the wall, and slope movements accelerated, leading to a significant collapse in the spring of 2003.

View of the Keillor Road slope failure one year later in 2004, looking to the north along the east bank of the North Saskatchewan River.

While initial investigations in 1995 indicated the slope failure was likely shallow and in the glacial sediments in the upper slope, more detailed studies after the 2003 slide indicated the slide was seated much deeper, likely in a bentonite seam in the Horseshoe Canyon bedrock, a few metres above the river.

There are numerous areas where active movement is visible in the lower portion of the slope in this stretch of the river, as evidenced by the lower portions of the slope, which consist of landslide debris (colluvium) that has failed from above and continue to be eroded away by the river.

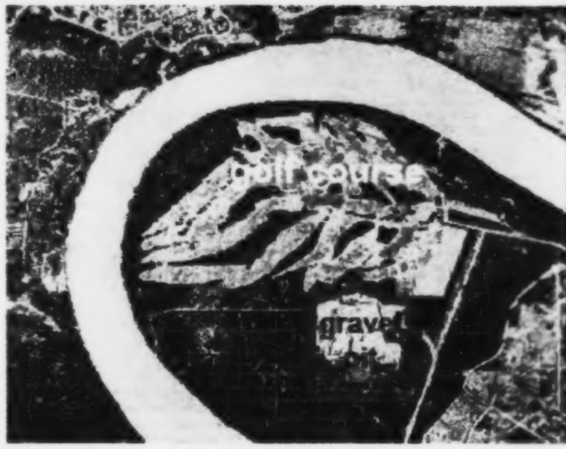
Stop 6: Hawrelak Park — Reclaimed Former Gravel Pits

We all know the geological resource most important to Alberta's economy is oil, but most are surprised to learn that number two on the top-10 list is sand and gravel. Sand and gravel are used primarily in making asphalt for roads and concrete for foundations, and when one considers how much we consume, it's easy to see how valuable sand and gravel are to Edmonton's economy.

While it may seem strange, not all gravel is created equally. The composition of the rocks making up the deposits determines how the material can be used in construction. For example, gravel used for concrete, which must withstand very heavy loads in foundations, must be made of rocks with great strength, such as quartzites. Only certain deposits, such as those in preglacial river channels, are suitable for concrete aggregate. On the other hand, gravel used for asphalt does not need to be as strong, and softer rocks, such as sandstone, can be suitable. These are the rock types typically found in gravel bars or river terraces along the North Saskatchewan River. As the city developed over the past 100 years, local deposits of sand and gravel were consumed first, then more distant sources were mined. Most local sources were found on floodplains on inside meanders of the river.

The following four figures are aerial photographs taken of the area now known as William Hawrelak Park. They show the sequential development of the floodplain meander from a golf course to a gravel operation to, lastly, a reclaimed recreational park. All four photos are modified from Godfrey, 1993: Edmonton Beneath Our Feet, Edmonton Geological Society.

Mayfair golf course area in 1924. Note the river scroll bars and absence of the Groat Bridge, Provincial Museum and the gravel pit south of the golf course.



Mayfair golf course area in 1952. Note the gravel pit south of the golf course and new housing developments.

Mayfair golf course area in 1962. Note the enlargement of the gravel pit and the construction of the Groat Bridge.

Mayfair golf course area in 1988. The gravel pit has been reclaimed and developed as William Hawrelak Municipal Park.

Stop 7: Summit Point/McKinnon Ravine

Prior to 2002, a large blue structure was erected on the west river bank that was highly visible from many areas of the city, especially travelling north toward Groat Bridge. This structure was a protective barrier to minimize erosion and infiltration of water into the slope. Between 2001 and 2002, prior to residential construction at this location, studies were completed to assess the subsurface geology and groundwater and their impact on slope stability. Studies confirmed the site was above the confluence of the buried Stony Valley and the larger Beverly Valley, the ancestral valley of the North Saskatchewan River. More than 40 metres of Glacial Lake Edmonton clay, till, and preglacial sand and gravel underlie the site, with groundwater seeping out of the lower slope just above the river. A weak bentonite zone was encountered in the bedrock below the channel floor, and was a concern with respect to slope instability. A series of horizontal pipes were installed to allow for easy drainage of groundwater from the channel sand and gravel, thereby reducing the build up of water pressure that could lead to a large slope failure.

Panoramic view of the McKinnon Ravine looking west from the Groat Road bridge area.

Stop 8: Mazama Ash at the High Level Bridge

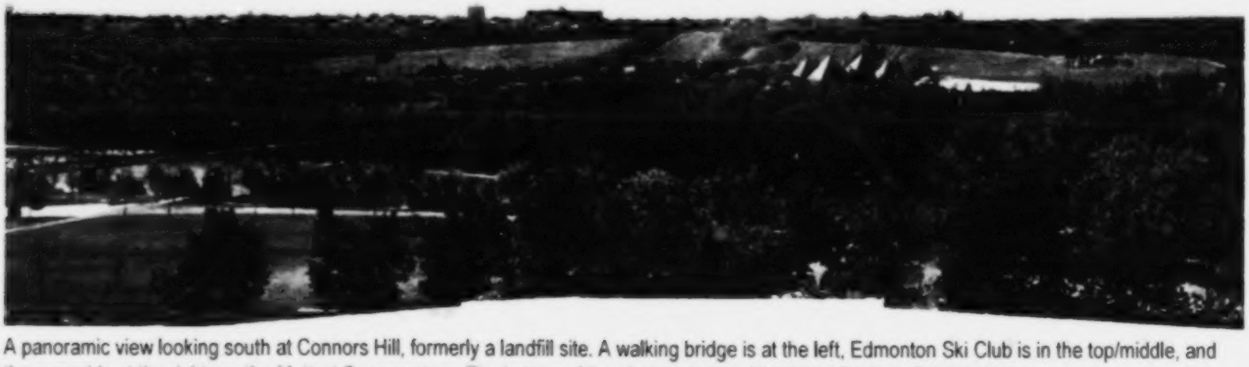
One of the most catastrophic events since the last Ice Age occurred more than 6800 years ago - the eruption of Mount Mazama in Oregon, about 1450 km south of Edmonton. The explosion was a hundred times greater than the Mount St. Helen's eruption in 1980. Seventy cubic kilometres of the mountain blew away and the ash plume covered almost 1.3 million km^2. The ash travelled as far north as Lac La Biche, which is 200 km northeast of Edmonton. The eruption drained the magma chamber causing the mountain to collapse inward, creating a 1200 m deep and 9 km wide caldera. This caldera is presently occupied by Crater Lake.

In Edmonton, the ash can be found as a 1 cm thick layer preserved along the lowermost terrace of the river. The ash is silty, pinkish-white and gritty because of the high volcanic glass content.

Layering on the river bank at stop number 8, just west of the High Level bridge/LRT bridge. The white layer between the two red lines is the Mazama Ash as seen in the close-up above.

Stop 9: Reclaimed Landfill of Connors Hill (Edmonton Ski Club and Muttart Gardens), Grierson Hill Instability, Shaw Conference Centre and Coal Mines. Pull out at Rafter's Landing.

Several factors contributed to the slope failure on Grierson Hill from 1901 until 1983. Four notable factors were the change in position of the river bank, the position of coal mines, weak bentonite beds and the added mass of waste dumped on a slump scar.

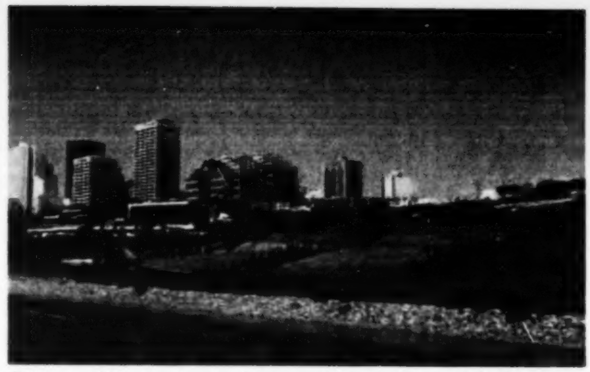


A panoramic view looking south at Connors Hill, formerly a landfill site. A walking bridge is at the left, Edmonton Ski Club is in the top/middle, and the pyramids at the right are the Muttart Conservatory. The bottom of the photo is Louise McKinney Park on Grierson Hill.

Before the Shaw Conference Centre could be constructed, a deep excavation removed more than the Centre's weight in soil so no additional mass was added to the top of the slope. Deep continuous piles were poured to support the back of the excavation before the slope was further steepened by more excavation. As the piles became exposed during excavation, they were anchored to the slope with long steel cables cemented in holes drilled through the piles and back into the slope beneath Jasper Avenue.

Construction on the Shaw Conference Centre. Photo is looking west with Jasper Avenue on the right.

Close-up showing the continuous piles poured to support the Centre and how they are anchored to the slope.



Grierson Hill today showing the graded, terraced, vegetated slope and the rip-rap armouring of the river bank. The view is to the north from the footbridge. The conference centre is at the left in the photo.

It was the abundance of coal that enabled Edmonton to so quickly become established as a city. Coal mines operated for nearly a century, with the last mine at Whitemud Creek closing about 1970.

Coal seams in the Edmonton area can be up to three metres thick and extended for many kilometres. In terms of quality, or ability to produce heat, Edmonton's coal is ranked as sub-bituminous. It burns for a long time with a bright flame and produces low amounts of ash. More than 13 million tonnes of coal were mined, most coming from the Clover Bar Seam. Mining was done almost entirely undergound and hauled to the surface along inclined slopes or vertical shafts. Most seams were about 1 to 1.5 m thick, so miners had to dig on their knees. The room-and-pillar system of mining was used, in which coal was extracted from a rectangular area (the room) leaving coal all around (the pillar) to take the weight of the rocks above. The miners then evacuated, hopefully before the pillars failed and the roof crashed down.

Present-day exposure of a coal seam along the south bank of the North Saskatchewan River near Lavigne (east of Rafter's Landing).


mudstone
bentonite
bentonite
mudstone

The development of natural gas supplies in Alberta spelled the end of coal as a fuel source in Edmonton, though most of Edmonton's and Alberta's electricity are still derived from coal-fired electrical generation facilities. Old mines were abandoned and most successfully reclaimed.

Location of underground coal mines in the Rafter's Landing area.

Pieces of coal are still found along the edges of the river.

References and Recommended Readings

Edmonton Beneath Our Feet - A Guide to the Geology of the Edmonton Region. Editor John D. Godfrey. Published by The Edmonton Geological Society, 1993.

A Traveller's Guide to the Geological Wonders in Alberta. R. Mussieux and M. Nelson. Published by the Provincial Museum of Alberta, 1998.

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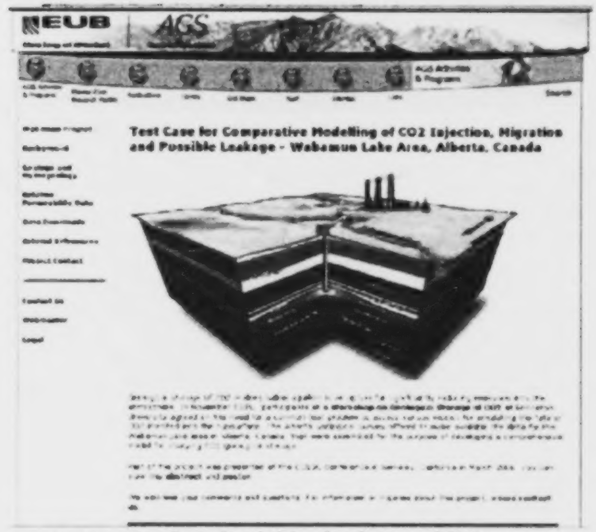

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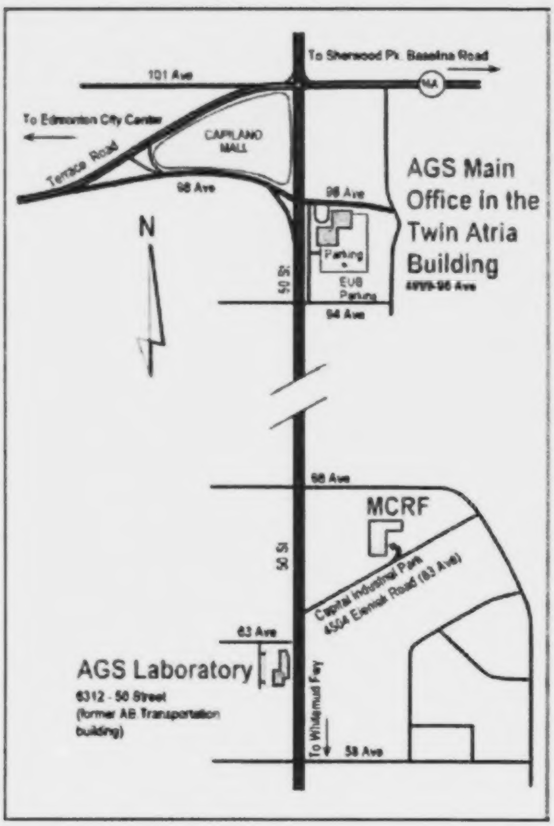

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